

30. HIGH FREQUENCY PLASMATRON TSNIIMASH AND ITS APPLICATION FOR AEROTHERMOPHYSICS STUDIES

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Abstract. The inductive High Frequency Plasmatron (HFP) in 1 MW power is described. This facility reproduced the real flight range of pressure, stagnation enthalpy and flight duration at altitude from 50 to 80km. In opposite of arcjet plasmatron the advantage of HFP consists in that the heating of working gas (air, nitrogen, CO_2) is result of electrodeless discharge. That is why the gas stream chemically pure. The general purposes of test in HFP are following: a comparative analysis of material and coating thermal stability against assumed heat load; prediction of rate constants for heterogeneous recombination of atoms on the surface of thermal protection materials (catalycity prediction); thermal and chemical stability of materials against oxidative action of dissociated air or CO_2 ; affect of pollution on the material catalycity, compatibility of different materials, life tests of thermal protection materials; testing of coatings together with structure fragments for determining their thermal regimes. Besides, today HFP is an ideal facility for MHD phenomena investigations in real flight conditions.

1. Experimental studies, combined with development of high-temperature materials for thermal protection of gliding vehicles (SHUTTLE, BURAN, HERMES, HOPE, Pre-X) and prediction of their catalycity, should be oriented to preliminary calculated estimations of aerodynamic heating and plasma parameters for typical vehicle's elements during its flight through the atmosphere. Such estimations permit to formulate requirements to experimental facilities and flow parameters, which are necessary to be provided under conditions of thermal protection materials specimens tests. These estimations should take into account an influence of nonequilibrium physical and chemical processes, substantial for flying vehicles of the given type at the most thermal-loaded part of the flight trajectory (altitudes $h \sim 85-55$ km).

For this goal the model numerical calculations of flow behind the detached shock wave in the vicinity of the vehicle nose bluntness (sphere radius $r_0=0.5$ m) were performed. In the pointed range of altitudes the Reynolds numbers are $Re = \rho_\infty V_\infty r_0 / \mu_0 \geq 10^3$, that permits to use method and algorithm of calculation [1], in which the flow behind the shock wave near a sphere is considered in the thick viscous shock layer approximation with modified Rankin-Hugoniot conditions at the shock wave, taking into account an influence of viscosity, heat conduction and diffusion.

The obtained data indicate that typical heat fluxes q_0 to the surface of gliding space vehicles reach their maximal values at pressures $p=8 \dots 50$ mbar and for the completely catalytic surface equal to $\sim 450 \dots 560$ kW/m² to the "hot wall". Corresponding values of the stagnation enthalpy are within the range $H_0=28-15$ MJ/kg.

The mentioned parameters are simulated in the high-temperature aerodynamic facility U-13HFP (TSNIIMASH) with high-frequency inductive heating of gas (HF-plasmatron).

To find out regimes of the facility operation, corresponding to real conditions of the vehicle BURAN, descending through the atmosphere, in addition to studies and diagnostics of flow parameters more detailed experimental and theoretical studies of heat transfer were performed using models of different configurations at different regimes of HF-plasmatron operation. In order to perform these studies, it was necessary to answer a whole number of questions, the major of them are as follows:

- ❖ determination of heat flux values depending on contributed power and plasma-forming gas flow rate, sizes and configurations of models;
- ❖ distribution of heat flux values over the flow cross-section, influence of starting flow whirl at the inlet into the discharge chamber;
- ❖ influence on heat transfer of factors of rarefaction, nonequilibrium occurrence of physical-chemical processes and catalycity;
- ❖ selection of conditions, optimal from the viewpoint of an accuracy in atom recombination rates constants determination;
- ❖ validation of possibility of numerical modelling heat transfer in the HF-plasmatron flow and extending of obtained data to real conditions;
- ❖ determination of boundaries of the region in which conditions of the flying vehicle descent through the atmosphere by heights and velocities of flight are simulated.

An important stage in performing of these studies was development of methods and programs for calculation of high-temperature gas flow in the discharge flow and in the stream [2].

The performed analysis indicated, that in HF-plasmatron subsonic flow it is possible to simulate major parameters governing heat transfer under real conditions of the vehicle flight through the atmosphere owing to varying plasma-forming gas flow rate and energy contribution. Such parameters are gas pressure p and stagnation enthalpy H_0 .

Important parameters in the heat transfer problem are also flow velocity gradient $a=(du/dx)_0$ and gas composition $c_{k\delta}$ at the outer edge of the boundary layer at the stagnation point of the flow on the model. The value of a is simulated in HF-plasmatron owing to performing tests in subsonic flow using models with relatively small size (significantly less, than the vehicle typical sizes). An important consequence of this is a possibility to simulate real values of heat- $\alpha/c_p \sim \sqrt{p \cdot a}$ and mass transfer $\beta \sim \alpha/c_p$ coefficients in tests. The values of $c_{k\delta}$, obtained as a result of calculations of nonequilibrium gas flow in HF-plasmatron, approximately correspond to the values of components concentrations behind the shock wave for parts of the vehicle trajectory being simulated.

Thus, separate simulation in HF-plasmatron flow of values of p , H_0 , mass concentrations $c_{k\delta}$ and α/c_p , typical for the vehicle flight conditions, leads also to simulation of real (or close to them) values of density, temperature, and also convective heat flux and diffusion fluxes of components (in particular, atomic oxygen) at the outer edge of the boundary layer.

2. Aerodynamic facility U-13HFP with power of 1MW (HF-plasmatron) with high-frequency inductive heating of gas was created in TSNIIMASH in 1982.

Major systems of the facility are high-frequency generator and high-frequency inductive plasmatron. The schematic is presented in Fig.1. Gas heating and plasma formation occur inside the discharge chamber 4, placed into the inductor 3. Voltage from the high-frequency generator is supplied to the inductor. This results, that inside the discharge chamber an alternating electromagnetic field with the frequency of 440kHz occurs. This initiates and maintains a discharge in gas being in the chamber. The working gas is supplied through the gas-former 16, passes through the discharge zone 15, where it is heated, and then it flows through nozzle 5 into the working chamber 7 and in exhaust channel trough diffuser 12. Specimens 8

for tests are placed on the special holder 9 with water cooling 13. The specimen is inserted into the gas flow 8, 14 with the input-output mechanism 10, 11. At the calibration stage on the input-output mechanism measuring probes and models are mounted. As a discharge chamber either the quartz tube, or the cooled chamber consisting of copper water-cooled sections placed into the quartz tube, is used. For the model temperature measurements with optical devices 1 the optical window 2 at the discharge chamber end is provided.

Performances:

Voltage, kV	0
Nominal power of HF-generator, N, kW	1000
Working gas	air, nitrogen, argon, carbon dioxide, etc.
Test chamber sizes, m	0.8 × 0.8 × 0.8
Electromagnetic field frequency, kHz	440 ± 11
Duration of continuous operation, s	up to 6000

The facility can operate both at subsonic, and at supersonic regime. Flow parameters obtained at such regimes are presented in Table 1.

High-frequency inductive heating of gas is realized at the expense of direct transformation of electromagnetic energy into heat. Such method has a number of advantages in comparison with electric-arc or ohmic heating. The principal qualitative distinction is absence of electrodes, that results in high chemical purity of heated gas, absence of any undesirable impurities, for example, products of electrode erosion, etc.). This is verified also by measurements using laser induced fluorescence method (LIF) [16]. From the other hand, high degree of dissociation, possibility to realize both subsonic, and supersonic flows of different gases (air, nitrogen, carbon dioxide, etc.), wide range of pressure variation $P=5...175$ mbar, possibility to vary flow parameters accordingly to a given program, practically unrestricted test duration - all this permits to test real materials under conditions typical for trajectories of descent through the atmosphere.

In particular, absence of contaminating impurities in plasma flow permits to study in HF-plasmatron such problems, solution of which in other high-temperature facilities either difficult, or impossible (determination of TPM catalysity, chemical compatibility of different materials, passage and attenuation of radio wave, etc.).

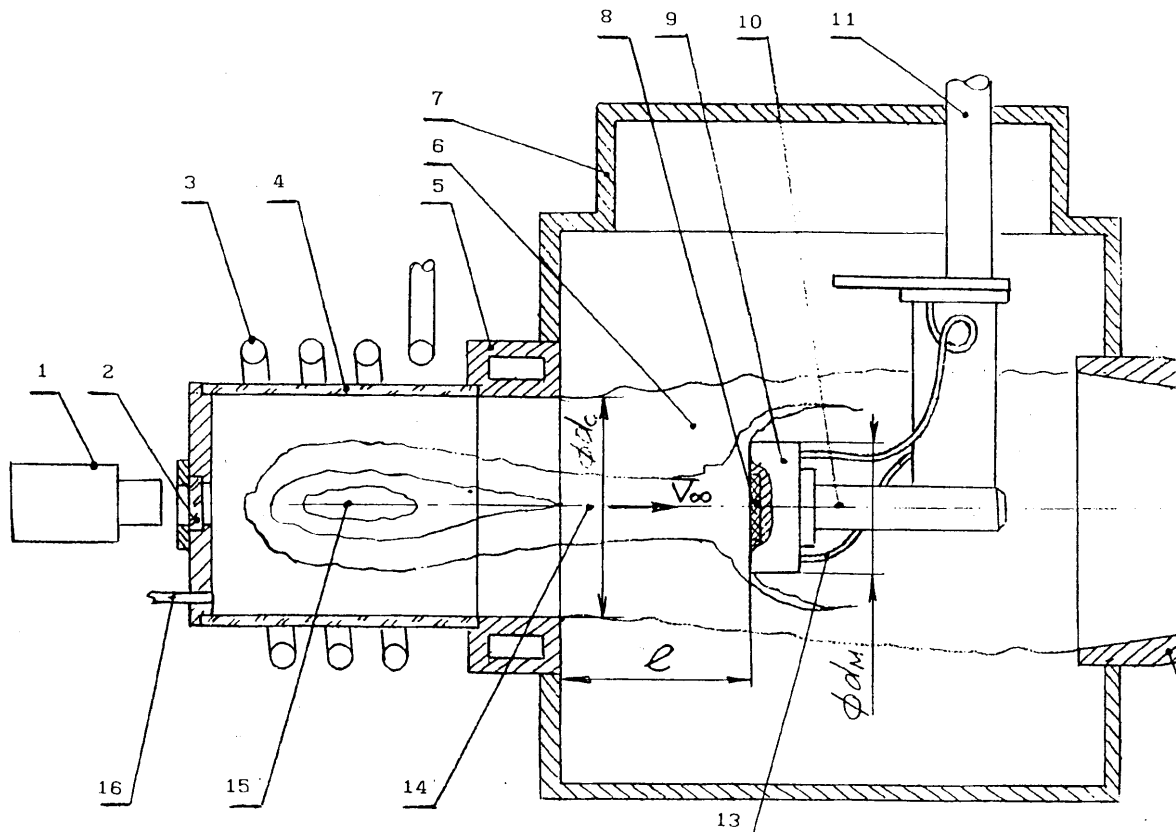


Fig. 1.

Regimes for TPS testing in HF-plasmatron TSNIIMASH

Table 1.

Regime	Working gas	Nozzle block	Outlet, mm	Model size, mm	P, mbar	H ₀ , MJ/kg	q _{cu} , kW/m ²	α/c _{p3} , kg/m ² s
Subsonic	Air	Cylinder	D=180	d=150	5-200	12-30	250-750	0.016-0.025
Subsonic	Air	Cylinder with additional gas supply	D=180	d=150	10-200	5-12	80-250	~0.02
Subsonic	Air	Cylinder	D=180	d=50	5-200	12-30	500-1200	0.03-0.04
Subsonic	Air	Convergent cone-cylinder	D=124	d=50	5-200	12-30	750-1900	0.045-0.06
Subsonic	Air	Flat (two-dimensional)	270×50	400×270	5-200	12-30	70-250	0.005-0.01
Subsonic	Air	Flat with additional gas supply	270×50	400×270	10-200	5-12	10-70	0.002-0.006
Supersonic	Air	Conical	D=50	d<40	~100	10-25	1500-2500	~0.1
Supersonic	Air	Conical	D=60	d<40	~20-40	10-25	2000-4000	~0.2
Subsonic	CO ₂	Cylinder	D=180	d=150	25-75	8-25	200-700	~0.025
Subsonic	CO ₂	Flat	270×50	400×270	10-75	8-25	70-200	~0.008

3. Different holders for specimens and different test schemes are used, depending on requirements to test conditions (heat flux levels, duration of the specimen being in high-temperature flow, etc.) [17]. The range of TPM surface temperature, realized in the process of tests, may be widened at the expense of selection of sizes of holders and specimens themselves. As a rule, two following test schemes are used: scheme "stagnation point" - the specimen surface is perpendicular to the gas flow velocity vector, and the scheme "plate" - the specimen surface is parallel to the gas flow velocity vector.

If specimens are tested using the scheme "stagnation point" and water-cooled copper holder in the shape of a cylindrical face with diameter of 150mm, sizes of specimens positioned in the middle part of the face are equal usually up to 65mm×50mm. In order to reduce edge effects caused by great temperature difference between TPM specimen and the cooled copper construction, a heat-insulating insert of low-conductive material based on quartz (tiled thermal protection of BURAN vehicle) is used.

On this holder at the values of contributed power $N=70-300\text{kW}$ heat fluxes are realized in the range $250\dots500\text{kW/m}^2$ (to high-catalytic copper surface, the working gas is air) at $p=1000\text{Pa}$, and some higher heat fluxes are realized at an increase in pressure ($q_0=700\text{kW/m}^2$ at $p=3000\text{Pa}$ and power $N=300\text{kW}$). Corresponding equilibrium temperatures at $\epsilon=0.9$ are equal to $T_{wr}=1400\dots1900\text{K}$. Since real TPM have a finite surface catalysity, then temperature, realized on its surface, may be substantially lower.

In order to obtain more high values of heat fluxes and the specimen surface temperatures, the holder with diameter of 50mm is used. Specimens with diameter of 25mm and thickness of 3...4mm are set into this holder, manufactured of siliconized graphite. The range of heat fluxes realized on such holder may be equal to $q_0=600\dots1400\text{kW/m}^2$, and the range of equilibrium surface temperatures may be equal to $T_{wr}=1850\dots2250\text{K}$ (at $\epsilon=0.9$, $\gamma=1$).

In order to increase heat fluxes above mentioned values the supersonic nozzle ($M\sim 2.5$) with flow stream diameter of $\sim 50\text{mm}$ is used. In this case $q_0\sim 2000\dots2400\text{kW/m}^2$, and pressure on the model $p_0'=50\text{mbar}$.

In case when TPM, and also structural elements, being in shaded areas or base region where heat flux levels are significantly below those on the vehicle windward size, are tested, the subsonic flat (slotted) nozzle with an outlet section of 270mm×50mm providing possibility to test TPM using the scheme "plate" is applied. With the use of this nozzle thermal protection panels and thermal protection packages (together with elements of a

metal construction) of sizes 270mm×400mm are tested. In case of using such nozzle heat flux levels can vary within the wide limits (from 20kW/m^2 to 200kW/m^2) both at the expense of variation of plasma-forming gas and energy contribution, and at the expense of variation of angle of set and model position. The value of heat flux to the model diminishes as it moves away from the nozzle outlet section.

In order to avoid high thermal stresses caused by high heating (or cooling) rate of the specimen, positioned on the model being input into flow, regimes of heating and cooling at which the value of dT_w/dt does not exceed typical real values of 6...8 degrees/s were developed. An additional supply of cool gas through the adapter collector, placed between the quartz discharge chamber and the nozzle block, is used.

4. Diagnostics of plasma flow is an integral element when performing every type of tests. [4-6].

In general case it is necessary to determine the following parameters: pressure p , density ρ , temperature T , flow velocity V , total enthalpy H_0 , mass concentrations of oxygen atoms c_0 and nitrogen atoms c_N . In principle, it is required also to know concentration of nitrogen monoxide NO and degree of ionization, but they are low under conditions of HF-plasmatron, and their contribution into common energy can be neglected.

Besides, at all usually used subsonic regimes (Mach number $M<0.3$) oxygen molecules are dissociated completely, i.e. mass concentrations of oxygen atoms c_0 is known ($c_0=0.232$), and the rest pointed parameters are not all independent, that results from the equation of state and relationship defining total enthalpy through T and V .

Hence, it is sufficient to determine experimentally only four parameters out of six parameters, governing plasma state in HF-plasmatron stream (P, ρ, T, V, H_0, C_N).

With pressure increase the gas state in the subsonic plasma stream comes close to equilibrium and number of independent parameters reduces.

At high-temperature gas flow diagnostics often not unknown parameters, but some quantities depending on them are measured. In order to determine the mentioned plasma parameters the following magnitudes are measured:

- static pressure;
- difference between total and static pressure;
- heat flux to the stagnation point of a sphere with radius of $R=24\text{mm}$;
- heat flux to the copper calorimetric model of the shape identical to the holder for specimen fixation;

- heat flux to the earlier well-studied low-catalytic tiled thermal protection material placed into the same holder, as specimens to be tested.

As already mentioned above, such set of measured parameters (five) with an addition of two algebraic relationships (equation of state and expression for gas enthalpy) permits in principle to determine unknown flow parameters: H_0 , V , p , ρ , T , C_N and velocity gradient a at the stagnation point of a model with a specimen (total seven unknowns).

Besides of measurements of above-described set of parameters, the following kinds of measurements were performed:

- measurements of stagnation enthalpy with an enthalpymeter [4];
- spectral measurements of near wake study behind models made of different materials [8];
- measurements of radiative heat fluxes to the model;
- measurements of radiation intensity of a stream in infrared spectrum range;
- measurements of electron concentrations with probes;
- measurements of gas composition, its thermodynamic and gasdynamic parameters using method of laser induced fluorescence [16].

Stable regimes with well-reproducible parameters of high-temperature air working streams were obtained in TSNIMASH HF-plasmatron in the range of pressures on a model of $p=5\dots 175$ mbar and stagnation enthalpy of $H_0=15\dots 35$ MJ/kg, the most interesting from the viewpoint of development and tests of thermal protection materials for vehicles of gliding descent.

5. As a result of selective chemical interaction between atomic oxygen and a covering material having a complicated composition, an increase in an outer layer roughness and a formation of pores are possible, that may cause the earlier laminar-to-turbulent heat transfer transition in the boundary layer, an increase in catalysity due to an increase in a quantity of active centres per unit area, and also some change in emissivity.

So emissivity (integral and spectral) and catalytic activity are among TPM properties, the most important for heat transfer analysis and varying as a result of operation.

An example of such changes in properties with time is the fact that the surface layer of SHUTTLE and BURAN thermal protection tiles becomes more gray, because the surface layer suffers loss of admixtures including boron compounds.

Two approaches to TPM tests on thermal resistance are possible. The first of them consists in performing of test at the given constant material

surface temperature. Such tests are of interest for material specialists, because they permit to study material behavior depending on temperature without taking the vehicle concrete construction and its operation conditions into account. Another approach consists in tests of materials at the given heat flux. The aim of such tests is study of a material, intended to be used for the concrete vehicle at known thermal loads.

Major parameters, those are to be simulated at such tests, are surface temperature, gas density (pressure) and mass transfer coefficient.

Since in the shock layer near a flying vehicle at the major part of a descent trajectory and in HF-plasmatron flow at all regimes oxygen is completely dissociated, then exact simulation of stagnation enthalpy in such tests is not required.

Under real conditions the value of mass transfer coefficient $\beta \cong \alpha/c_p$ varies with time (with height of flight), and in HF-plasmatron it is practically constant, so it is necessary additionally to meet the condition

$$\int J_0^*(t) dt = J_0 \Delta t \quad (1)$$

Here $J_0^*(t)$ and J_0 are diffusion fluxes of oxygen atoms under real conditions and in HF-plasmatron, Δt is test duration, which is determined just from this condition. It may differ from duration of flying vehicle descent through the atmosphere.

So TPM tests on thermal chemical resistance with respect to oxidizing action of atomic oxygen must be performed at several values of T_w (determined by corresponding giving of heat flux values q) and pressure p , and is test duration must be determined with taking (1) into account.

Just the second approach is discussed in this section. Procedure for thermal protection materials tests on thermal chemical resistance with respect to oxidizing action of high-temperature dissociated air flow with high content of atomic oxygen includes a whole number of stages and operations:

1. Analysis of trajectory parameters and determination of test conditions: pressure, enthalpy, stagnation enthalpy, heat fluxes and atom diffusion fluxes, etc.
2. Selection of a holder and specimen sizes for performing of tests. Calculation of temperature regime of a holder and a specimen under conditions of plasma flow action with the aim to determine time of going into stationary regime, heat flux leakages, pressure differences across the material thickness and surface.
3. This requires to know material thermal physical properties (ρ, λ, c_p) and optical properties of

- covering (ε), and also (if necessary) their dependencies on temperature and pressure.
4. Performing of preliminary tests on determination of specimens and coverings workability at different levels of pressures and heat fluxes. In this case as reference heat flux values the values of q_{Cu} heat flux to the copper model with geometry identical to geometry of the model with the specimen, are used.
 5. Selection of the facility operation regimes. With this aim a whole number of tests with a copper calorimetric model, having a shape as that of the selected holder for specimens. Tests are performed at the selected pressure value, and the value of heat flux q_{Cu} is varied owing to energy contribution variation. At the given restrictions on the specimen heating rate dT_w/dt additional tests on selection of the facility necessary parameters to reduce dT_w/dt at going into regime and at its leaving.
 6. Diagnostics of plasma flow at test regimes.
 7. Selection and preparation of measuring instruments.

The following parameters are measured in the process of TPM tests in TSNIIMASH HF-plasmatron:

- pressure in the test chamber;
- electric characteristics (current and anode voltage);
- specimen back surface temperature with thermocouples, positioned in the isothermal cavity;
- external surface temperature and its distribution with optical devices, operating in infrared spectrum region ($\lambda=3\dots5\mu\text{m}$).

Different thermocouples are used depending on test regime (expected level of T_w) chromel-alumel at $T_w=1300\dots1600\text{K}$ ($\Delta T/T=0.7\%$ at $T=1600\text{K}$),

- platinum-platinum-rhodium at $T_w=1500\dots1800\text{K}$ ($\Delta T/T=0.25\%$ at $T=1800\text{K}$),
- tungsten-rhenium at $T_w=1700\dots2300\text{K}$ ($\Delta T/T=0.7\%$ at $T=2300\text{K}$).

Thermocouples are placed into the isothermal cavity behind the specimen and do not touch the surface of the specimen under test. Temperature at a test stationary regime measured with such thermocouple is, as a rule, lower than the surface temperature T_w of the material of type C/C by the value of $5\dots25\text{K}$, depending on properties of the material under test and on test regime.

The pyrometer of Maurer firm, operating in the wavelength range $\lambda=4.5\dots5.5\mu\text{m}$, and the scanning IR-camera AGA, operating in the wavelength range $\lambda=3.5\dots5.5\mu\text{m}$, are used for measuring T_w of the external surface. In the latter case it is possible to use filters, transmitting

emission in more narrow wavelength ranges. The uniformity of T_w distribution over the specimen is also controlled with the IR-camera.

Visual inspection weighing and photographing of specimens are carried out before and after tests.

6. Other kinds of tests.

6.1. Study of material catalytic properties in HF-plasmatron and comparison with flight tests

In TSNIIMASH, in order to predict TPM catalytic activity, the experimental-calculational method based on heat flux measurements to different materials in well-diagnosed dissociated gas flow (nitrogen, air, CO_2) and calculations of nonequilibrium boundary layer on the model surface with an arbitrary catalysis was developed [5,7,9,10]. This method was approved and widely used under tests of the vehicle BURAN thermal protection materials catalysis, and also at realization of contracts with DASSO firm and AEROSPATIALE (France), with ESA, with Mitsubishi (Japan), etc.

The values of K_w for the vehicle BURAN thermal protection materials, predicted with the use of the method, were supported by flight tests results.

6.2. Study of influence of different kinds contaminations on thermal protection materials catalytic activity

Contamination of the vehicle thermal protection surface, causing changes in its physical (mainly, emissivity) and physical-chemical properties (catalysis) and increase in values of heat flux and equilibrium temperature, may occur due to a whole number of reasons, connected both with preflight preparation, and with features of operation [12].

The following kinds of contaminations were studied:

- influence of destruction products from ablating thermal protection materials of BURAN-to-ENERGIA communication unit on K_w of the tiled thermal protection;
- influence of jets from solid-fuel engines for carrier-rocket ENERGIA blocks separation on K_w of BURAN tiled thermal protection;
- influence of protecting lacque, technogeneous contaminants (machine oil) and sea water on K_w of tiled thermal protection;
- influence of copper vapors, depositing on to thermal protection materials surface during their tests in electric-arc-jet facilities, on K_w

6.3. Study of “catalytic sublimation” and glow near the model surface in plasma flow

During TPM tests in subsonic plasma flow novel physical effects, connected with complicated character of proceeding of heterogeneous processes on its surface. The material mass loss under action of energy being released at recombination (“catalytic sublimation” [11]) and near-the-surface gas glow, connected with formation of electron- and vibrationally excited molecules [12,13] in heterogeneous reactions, are among them.

6.4. Resource multicyclic tests

Resource tests are performed accordingly to the procedure in 5 with meeting requirements to specimens heating rate during going into regime and to their cooling rate during going from regime. The required values of pressure, total enthalpy and heat flux are provided at the stationary part with duration up to 1200s.

6.5. Control for TPM emissivity variation

The material emissivity ε may be varied at resource multicyclic tests due to oxidizing action of atomic oxygen. If to use argon as a working gas (catalytic effects in argon are absent just owing to the fact that it is monoatomic, then variation of ε may be controlled, because the difference between surface temperatures at different materials observed under tests is caused only by their different emissivity.

6.6. Tests of individual elements and fragments of constructions

Different kinds connectors constructions, by means of which power was supplied to BURAN at its pre-flight preparation at the start were also performed in TSNIIMASH HF-plasmatron. The objective of such tests was to determine chemical compatibility of connectors materials and major thermal protection materials.

6.7. Other types of testing

In addition to above listed types of testing there are also performed in HF-plasmatron the following studies:

- influence of ablation products of TPM on radiowave propagation through plasma in the wake behind the model;
- recombination glow of gas in boundary layer on model surface;

- spectral measurements of gas emission in boundary layer on the model and in the wake behind the model.

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At high radio frequencies, above 30 MHz, the natural EM-fields originate from very broadband blackbody radiation from the warm earth and from extraterrestrial processes, mainly from the sun and the extraterrestrial microwave background radiation from the whole sky (Kraus 1986; Burke and Graham-Smith 1997). It should be noted that only at frequencies above 30 MHz and below 30 GHz do electromagnetic waves penetrate the atmosphere efficiently. Apart from the access frequency of 217 Hz and its harmonics, there are various control and system signals giving rise to power variations at the frequency of 2 and 8 Hz. Exposure to high frequency electromagnetic fields, biological effects and health consequences (100 kHz-300 GHz). Its equation of motion is derived from a force equation that balances the rates of change of momentum of the spacecraft and the ejected matter: $m\ddot{\mathbf{r}} = \dot{m}\dot{\mathbf{r}} + \mathbf{v}_g$, (1.1). Studies have also shown that CCPs may also experience mode transitions (from E to H) if they are driven at high frequency because of an induced field parallel to the electrode [21, 22]. Both of these phenomena will be discussed in later chapters. Finally, there is a third regime that couples energy from the RF fields to the plasma, labelled W for wave. Electrons have a small mass and, in gas discharge plasmas, a high temperature. Using the typical value of $T \approx 30\,000\text{ K}$ leads to $v_e \approx 10^6\text{ m s}^{-1}$. This is much larger than the typical drift speeds observed in the plasma.

30. high frequency plasmatron tsniimash and its application for aerothermophysics studies. Article. V B Knotko. High Frequency Plasmatron (HFP) with 1 MW power [11] for reproduction of real flight range of pressure, stagnation enthalpy and flight duration at high altitude, is used in the Central Research Institute of Machine Building in Moscow. In HFP, the heat flux in supersonic conditions reaches 2400 kW/m^2 . Reference: Plasmatron for Simulation of Re-entry Conditions in a Planetary Atmosphere. Extended Possibilities for Simulating Re-entry Conditions of Space Vehicle in HF-Plasmatron. Citing article. Frequency 30-300 Hz 3-30 KHz 30-300 MHz 3-30 MHz 30-300 MHz 300-3000 MHz 3-30 GHz 30-300 GHz. Wavelength 10-1 Mm 100-1 Km 1 Km-100M 100-10m 10-1m 1m-10 cm 10-1 cm 1 cm-1 mm. The following table shows the main application in each frequency range. AM broadcast band Short wave radio FM broadcast band VHF TV (2-4) VHF TV (5-6) UHF TV (7-13) UHF TV (14-83) Microwave Radio links and Satellite Communication Mobile Telephony. These values for the high gain antenna refer to the intended direction of maximum radiation and decay rapidly away from that direction at a rate depending on the shape of the radiation pattern of the particular antenna. A set of measurements were performed around the site and the maximum power density found was 52 mW/cm^2 . Plasmatron High Voltage Supply. 30 Jan 2013. staffElectronics. High frequency plasma circuit (Electronic Ion Pump). This circuit utilizes a flyback transformer that has wire windings added to its ferrite core. The high-voltage, high frequency is the result of the transformer being driven into resonance at 20 to 170Khz. The flyback transformer supplies high-voltage, high frequency. Its output is in harmony with the Sea of Energy that surrounds it. Like the waves of the ocean, coming and going in regular beat notes, it is in tune with the radiant energy that surrounds its output. This source can